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Gillian Key
Biological Sciences, Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester Ml 5GD, United Kingdom

Elizabeth Wilson
Biological Sciences, Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester Ml 5GD, United Kingdom

Jules Conner
Biological Sciences, Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester Ml 5GD, United Kingdom

PRESENT STATUS OF *RATTUS NORVEGICUS* ON SANTA CRUZ ISLAND, GALAPAGOS, ECUADOR

GILLIAN KEY, ELIZABETH WILSON, and **JULES CONNER,** Biological Sciences, Manchester Metropolitan University, John Dalton Building, Chester Street, Manchester Ml 5GD, United Kingdom.

ABSTRACT: Introduced commensal rodents have had a major impact on the biota of island communities worldwide; the ship rat *(Rattus rattus)* and the house mouse *(Mus domesticus)* have a long history in the Galapagos islands, while the larger, more aggressive brown rat *(Rattus norvegicus)* was identified only in 1983 on one island, Santa Cruz. By 1988 it had spread into the agricultural zone but was still restricted to human habitation. In 1993 the cross-island road and village communities in the agricultural zone of Santa Cruz were sampled using a standard trap line of break-back traps. House surveys were also carried out, where appropriate. The brown rat was found to occur at all sites sampled on the south side of the island, including sites independent of human habitations, and is now the dominant commensal rat in houses. The impact of the brown rat on the ship rat and the conservation implications of its spread are discussed.

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INTRODUCTION

World biodiversity is greatly enhanced by the large number of rare organisms on oceanic islands where isolation has led to the evolution of unique assemblages of plants and animals. The high levels of endemism are associated with high extinction rates and increased vulnerability, particularly to disturbance in the form of introduced exotics. Among these the commensal rodents are some of the most widespread and destructive. In 1980 it was estimated that rats had reached around 82% of the world's islands or island groups (although rat free islands existed within most groups) (Atkinson 1985; Moors et al. 1992), and in the intervening 13 years their range has undoubtedly expanded. Introduced commensal rodents have had a major impact on the flora and fauna of islands systems, resulting in many cases of local or global extinctions of various groups, from invertebrates to reptiles (Dingwall et al. 1978; Moors 1985a; Moors et al. 1992; Wace 1986). The Galapagos islands in the Pacific ocean are one of the most well known of oceanic island groups and in recognition of their importance they were designated a World Heritage Site by UNESCO in 1979 and a Biosphere Reserve in 1985; they have been a National Park since 1959. Feral mammals pose one of the biggest threats to the unique and fragile Galapagos ecosystems by causing habitat destruction and by direct predation on native fauna. The commensal rodents were probably among the first introductions with the use, and then the settlement of the islands by man in the 1600 to 1800s (Key & Munoz, in press; Patton et al. 1975). The house mouse (MM* *musculus)* and the ship rat *(Rattus rattus)* are now widespread with the former species occurring on seven islands, and the latter on ten. The brown rat *(Rattus norvegicus)* is a recent introduction only known to occur on Santa Cruz island. Rats are a major pest in both the settled and Park areas; in the towns and agricultural zone they cause structural damage and attack stored goods and growing crops, in addition to their potential for spreading diseases of both man and livestock (Meehan 1984). In the Park, rats take the eggs and chicks of ground nesting seabirds and mocking birds, and also attack the eggs and newly emerged young of giant tortoises and iguanas (Cruz & Cruz 1987; Duffy 1981; Kramer 1974). In this context rats are a serious conservation problem and rat control is a major part of Galipagos National Park management.

Santa Cruz island is the base for the largest town in the islands, Puerto Ayora, and is the only island with the full range of vegetation zones still extant; it also has breeding areas of the endemic race of giant tortoise *(Geochelone elephantopus)* and of the endemic endangered dark-rumped petrel *(Pterodromaphaeopygia).* The house mouse arrived on this island some time just after the second world war; *R. rattus* was seen for the first time in the 1930s, but *R. norvegicus* has been present only since 1982 to 1983 (Key and Munoz, in press). The arrival of the latter has serious management implications for the Park if it succeeds in expanding its range beyond human settlements, as it is a larger, more aggressive species capable of attacking chicks and young tortoises and iguanas of greater size than can the ship rat. This has serious financial implications in the captive breeding and petrel protection programs on the islands. In 1988 a study was made of the distribution of *R. norvegicus* on Santa Cruz, and it was found to occur in Puerto Ayora and Bellavista (the main village in the agricultural zone) but not outside the confines of houses, and *R. rattus* was still the dominant species (Sivinta 1988). The study described here aimed to assess the distribution of *R. norvegicus* in 1993, define the area of overlap between the two species and examine the impact of the relatively recent *R. norvegicus* on *R. rattus* populations.

SITE

Santa Cruz (9 10' 05", 0 22' 21") is the second largest island in the archipelago with a surface area of 986 km^2 and highest point of 864 m. It consists of one major volcanic cone and several parasitic cones, with a gently sloping topography at lower elevations, becoming steeper at higher elevations. As the altitude increases, so does precipitation and erosion, resulting in a substrate gradient of lava boulders at lower elevations, changing to soil of up to 3 m deep at the highest altitude (van der Werff 1980). These changes in precipitation and substrate result in distinct vegetation zoning with six zones being recognized: littoral or arid, transition, Scalesia, brown, Miconia, and pampa. Full details of vegetation and other characteristics of each zone are given in Jackson (1985) and Wiggins and Porter (1971). Agriculture is possible in four higher altitude zones-transition, brown, Scalesia and Miconia.

The climate is typically dry and bi-seasonal, with the main rains falling from July to December in the highlands and in the lowlands from January to June. The study was carried out from July to September 1993, 1992 had been an El Nino year; El Nino being a recurrent atmospheric phenomenon which on the islands results in unusually heavy rains falling between December and April; lowland vegetation was still green and lush well into August in 1993.

METHODS

Nine sites were chosen across Santa Cruz representing various aspects of the island in terms of vegetation, agricultural and urban characteristics (see Figure 1). Most sites were situated along the cross-island road, not only for ease of access but also as the road was considered the most likely means of dispersal of brown rats in association with the activities of man.

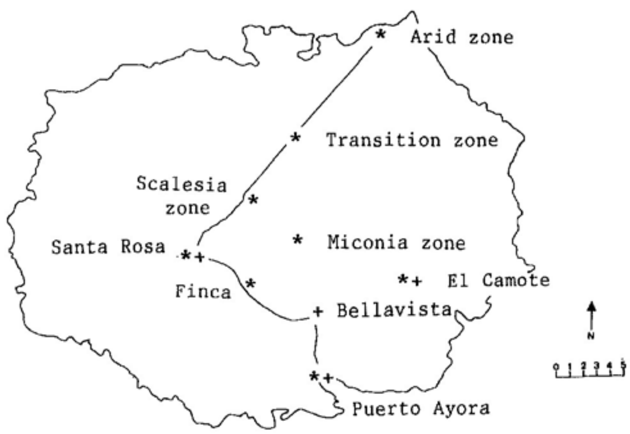

Figure 1. Santa Cruz island, showing the cross-island road and sampling areas: * line transect only, *+ house survey and line transect, + house survey only.

At each site, a group of five break-back traps were placed every 20 m along a 400 m line. Each group consisted of three wooden and two metal traps placed in areas frequented by rats, as indicated by the presence of tracks and droppings. Trapping was carried out for a total of three nights, setting traps between 1630 h and 1800 h and disarming them at 0600 h, at which time any rats caught were collected; disarming the traps during daylight hours reduced the risk of catching non-target species. Various baits were used, namely peanut butter, fruit chunks, banana and cheese. After collection, the following autopsy measurements of the rats were taken: length of the head and body, tail, ear and hind foot, the weight, sex and reproductive status, distinguishing juvenile (abdominal testes, non-perforate vagina) and adult (scrotal testes, perforate vagina) and for adult females noting the incidence of lactation, pregnancy, and the number of embryos.

In the Miconia zone, live traps (Tomahawk design, 40 x 12 x 12 cm) were used in conjunction with the break-back traps in order to compare the trapping efficiencies of the trap types. A single live trap was placed along the transect between each group of five break-back traps.

Four of the sites were settlements (Santa Rosa, Bellavista, El Camote and Puerto Ayora) and here a house survey was also carried out. Residents were asked to place two to five baited break-back traps in their houses, depending on the size of the building, giving a mean density range of 2.18 traps/house (Pto. Ayora) to 4.00 traps/house (El Camote). As with the traps along the transect, traps were set just before dusk, rats collected at 0600 h when the traps were disarmed. This study was also continued for three nights at each site, and the same autopsy data recorded from the rats.

To determine the extent of any domestic pest control, residents involved in the house survey were asked if they had a problem with rats, and if so, how they controlled them.

RESULTS

In the line transect, a total of 57 *R. rattus* and 12 *R. norvegicus* were caught (see Table 1); 20% of female *R. norvegicus* were pregnant and there were no pregnant ship rats. *R. norvegicus* was caught only on the south side of the island up to the Scalesia zone, and the present distribution of this species is shown in Figure 2.

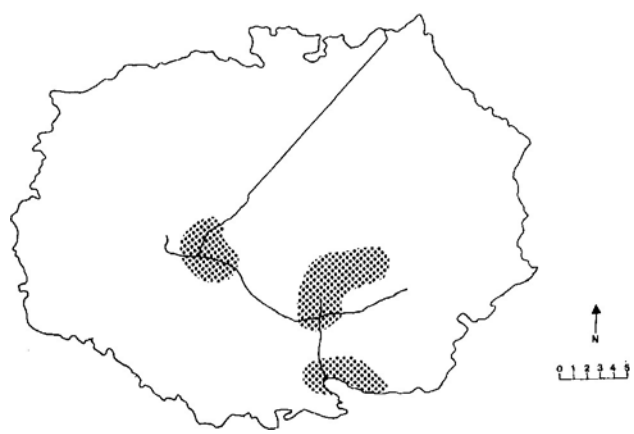

Figure 2. Santa Cruz island, showing the 1993 distribution of the brown rat, *R. norvigicus,* (dark stipling).

In the comparison of trap types, significantly more rats (combining data for both species) were caught in metal break-back traps than in wooden ones ($t=7.015$, $p<0.01$), and in live traps than in break-back traps ($X^2=25.6$, $df=3$, $p<0.05$) (see Table 1, Miconia zone a and b for break-back and live trap catch respectively).

In the house survey, a total of 11 *R. rattus* and 72 *R. norvegicus* were caught (Table 1) with a mean density of

Table 1. Numbers of rats caught at each site in the line and house transects: male (m), female (f), unknown (u)* and total (n); in the Miconia zone the results of break-back trapping (a) and live trapping (b) are shown.

	R. rattus				*R. norvegicus*			
Site	**m**	**f**	**u**	**n**	**m**	**f**	**u**	**n**
Line transect.								
Pto. Ayora	3	5	0	8	0	0	0	0
Arid zone	2	3	0	5	0	0	0	0
Transition zone	9	3	1	13	0	0	0	0
Scalesia zone	2	1	1	4	2	1	0	3
Finca	1	0	1	2	0	1	0	1
Santa Rosa	2	1	0	3	2	0	0	2
El Camote	3	2	1	6	0	0	0	0
Miconia zone (a)	1	5	1	7	0	1	0	1
Miconia zone (b)	3	6	0	9	2	3	0	5
Total:	26	26	5	57	6	6	0	12
House survey								
Pto. Ayora	5	1	0	6	24	7	0	31
El Camote	0	1	1	2	4	2	0	6
Santa Rosa	0	1	0	1	2	1	0	3
Bellavista	1	1	0	2	5	24	3	32
Total:	6	4	1	11	35	34	3	72

***sex unknown as the body was largely consumed by other rats.**

rats/house ranging varying from 0.23 (Santa Rosa) to 2.00 (El Camote); 23.5% of female *R. norvegicus* were pregnant and there were no pregnant ship rats. The majority (88%) of the traps were baited with meat and 81% and 100% of the *R. norvegicus* and *R. rattus,* respectively, were caught in these. The other baits used were in equal proportions and catching equal numbers of rats, tripe, fish and maize. The response to the questionnaires is shown in Table 2. Overall, 70% of people questioned claimed to have problems with rats, and use of poisons (Racumin, 0.0375 - 0.075% coumatetralyl, and 1080, sodium monofluoracetate) was the most common method of control.

Sex ratios were close to parity for both species, in both house and line surveys (Table 1). Overall, there was a predominance of juvenile (31) over mature (21) ship rats, which was primarily due to specimens caught in areas of allopatry (76 % juvenile; 51 % juvenile in areas of sympatry) with *R. norvegicus.*

The quality of the rats caught in the different sites was compared using the body condition index of Moors (1985b) as one potential measure of the impact of the brown on the ship rat: $C = \frac{W}{HBL^3} \times 10^s$

where W = body weight (g) and HBL = head and body length (mm). There was no significant difference between *R. rattus* specimens caught in the line transects in areas of sympatry and allopatry with *R. norvegicus* ($t=0.209$, $p>0.05$), or between houses and associated lines ($t=0.046$, $p>0.05$). Simple body weight was also examined for ship rats in the two areas, and was found to be non-significant ($t=0.026$, $p>0.05$).

DISCUSSION

Catches overall were much lower than expected, in a post-El Nino year on an island where the ship rat population has been described as one of the highest in the world (Clark 1978). This could have been due various factors, such as the baits used or the trap type, the metal traps being more efficient than the wooden types which were in the majority. For ft. *norvegicus* there is the

Table 2. Perception of rat problems and treatment in houses involved in the survey.

	Santa Rosa 14 (n)	Bellavista 38 (n)	El Camote 3 (n)	Pto. Ayora 55 (n)
Problems with rats only	14	30	3	30
Problems with mice only*	0	5	0	2
Methods of control:				
Traps	1	5	0	6
Poison	14	28	3	25
Residents with rats but not attempting control:	0	1	0	1

*Volunteered by the house holder and not specified in the questioning.

additional factor of neophobia (Meehan 1984) and the fact that each site was only sampled for three nights. In the line transects, sampling relatively stable environments, this may have been insufficient time to overcome the response and results should be viewed accordingly. However, the brown rat has increased its range on Santa Cruz island from that recorded in 1988 by Sivinta (Puerto Ayora and Bellavista) to the highlands on the south side of the island, outside the inhabited areas, and it is now the dominant rat in the villages sampled. Whether it will eventually eliminate or simply displace *R. rattus* remains to be seen. The brown rat has not had a significant impact on the ship rat in terms of the body condition index, but other work carried out at the same time on the behavioral ecology of the two species indicated that ship rats are more arboreal in areas of sympatry with brown rats (Woods 1994), suggesting a preliminary, at least, displacement of one species by the other. Brown rats have been found to displace ship rats in other situations (Armitage 1993; Atkinson 1985), although the two species can co-occur, with a displacement of *R. rattus* (Taylor 1975; Watson 1961). Either way, the brown rat can be expected to become widespread over Santa Cruz and is already abundant in the dark-rumped petrel breeding area. Imber (1978) and Moors and Atkinson (1984) predicted that the impact of rats on breeding petrels would increase with parity of body weights and decreasing density of petrel nests. The brown rat (250 to 350 g body weight) is more nearly equal in weight to the dark-rumped petrel [ca 400 g body weight (Simons 1985)] compared to the smaller ship rats (range of 100 to 200 g). The density of petrel nests in the Galdpagos also appears to be relatively low, although exact figures are not available; Imber considers a density of 207 burrow/ha to be low while Simons notes 6.7 burrow/ha as a maximum density for the Hawaiian subspecies of the dark-rumped petrel, and Cruz and Cruz (1987) found 500 breeding pairs in an area of approximately 35 km^2 in the Galapagos, giving a density of 0.7 burrows per ha. These two factors indicate a higher potential impact of brown rats on petrels. The larger size of the brown rat also suggests that larger petrel chicks will be attacked; there are sources for brown rats attacking live adult petrels and other seabirds as well as eggs and chicks (Drummond 1960; van der Elst and Prys-Jones 1987). Bettesworth and Anderson (1972) found that on Whale island in New Zealand brown rats were primarily carnivorous in the breeding areas of petrels, and petrel chicks comprised the main component of the diet. However, Pye and Bonner (1980) found that brown rats on South Georgia had co-existed with several species of petrels and prions for over 150 years, and only found evidence for a negative relationship between rats and Antarctic pipits, with the latter only nesting in rat-free areas. The impact of rats on seabirds is therefore variable and clearly there are several factors involved, making predictions unreliable.

On the Galapagos islands giant tortoise eggs and young are also vulnerable to rats. At present, tortoise hatchlings in the captive breeding centre at the Charles Darwin Research Station have to be protected from rats for five years (Marquez et al. 1987). The presence of brown rats here, if they are found to predate the young (and there is no reason to suppose that they will not) will require a longer period of protection and concomitantly larger input of resources to maintain the young in captivity.

The spread of the brown rat to higher altitudes is not unexpected, as the deeper soils and moister conditions favor this species as a burrowing rather than a climbing species (Buckle and Fenn 1992; Atkinson 1985) with a daily need to drink (Meehan 1984). The spread of the brown rat is therefore facilitated and it is unfortunate that it arrived on the most favorable side of the island. If the two species of rat can co-exist on this island it would be expected that the brown would dominate in the highlands and the ship rat be displaced to the marginal, dry coastal areas.

No pregnant ship rats were caught during the project. The seasonal nature of breeding in both species of rat has been noted by various workers (Clark 1980; Moors 1985b) with protein identified as the limiting factor. In houses protein would be more readily and consistently available allowing breeding to take place in the dominant species found here, the brown rat. Even when protein was apparently available all the year round in South Georgia, brown rats showed seasonal breeding (Pye and Bonner 1980), and the effects of the El Nino in 1993 may have simply prolonged the breeding season beyond normal where resources allowed.

When live traps were placed along the break-back trap line and run simultaneously catch in the live traps was significantly higher. Rat monitoring is frequently carried out during visits to other islands in the archipelago using a small number of snap-traps run for, often, only a few nights. In order to have more confidence in the results (especially those that find no rats), it is recommended that live traps be used in future as Galapagos rats appear to be more susceptible to capture in these.

The brown rat has arrived to stay on Santa Cruz, at least for the foreseeable future. Its expanding range and the apparent ideal nature of large parts of the island make its establishment as the dominant species, at least in the highlands, inevitable. Eradication is not impossible; with the development of the modern second generation, single feed anticoagulants, eradication of rats from even quite large islands has been achieved, from 9 ha (Hawea island; Taylor and Thomas 1989) to 170ha (Breaksea island; Taylor and Thomas 1993). The inhospitable volcanic terrain, thorny vegetation, lack of water and size of the Galapagos islands makes control programs extremely difficult to carry out. The priority is to prevent the spread of *R. norvegicus* to other islands in the archipelago in view of the increased impact expected of this species. The risk is great, as this species is abundant along the docks and port area of Santa Cruz from which many tourist, residents and fishermen's boats depart daily, which makes landings on both inhabited and uninhabited islands possible. Fisherman pose a particularly acute hazard as their landings are harder to regulate, both in terms of location and frequency (Moors et al. 1992). An effective urban rat control campaign, in itself of great benefit to the residents of the Galapagos islands and in creating good will between residents and National Park Service, together with adherence to guidelines such as those detailed by Moors et al. (1992) would go a long way towards minimizing the risk of spread of commensal rodents to vulnerable islands.

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